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DETERMINATION OF THE WELDING CONTROL PARAMETERS AND REQUIREMENTS FOR THE AUTOMATION OF OUT-OF-POSITION WELDING

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INTERNATIONAL AIRPORT LOS ANGELES 9, CALIFORNIA

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NORTH AMERICAN AVIATION, INC.

INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIFORNIA

ENGINEERING DEPARTMENT

(2) Metallic materials Lab.

(NASA Contract NAS8-2601)

(NASA CR-55821;

DETERMINATION OF TIG WELDING CONTROL

PARAMETERS AND REQUIREMENTS

FOR THE

AUTOMATION OF OUT-OF-POSITION WELDING

Unc.

[redacted]

PREPARED BY

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FOREWORD

This report presents the work accomplished for the Phase III Part of the NASA Contract NAS8-2601, "Determination of TIG and MIG Welding Control Parameters and Requirements for the Automation of Out-of-Position Welding." This report includes the results obtained from tests to determine the feasibility of out-of-position automatic welding with the oscillating MIG process.

TITLE: "Determination of TIG Welding Control Parameters and Requirements for the Automation of Out-of-Position Welding."

AUTHOR: J. Lambase 16832 A

ABSTRACT: In Phase III the oscillating TIG unit built and tested in Phase II was modified for the MIG process. Modifications were made to position the MIG gun on the unit, provide variable dwell and to incorporate an adjustment to change the angle of rotation. Acceptable oscillating weld passes with good side wall fusion were made. Weld bead widths ranging from 1/4 to 1-1/2 inches were obtained with the modified oscillator on 2 and 2-1/2 inch thick aluminum plate. The Phase III results indicated that it is feasible to out-of-position weld with the oscillating MIG process.

Author

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INTRODUCTION

The size of future space launch vehicles may require on-site fabrication with a need for welding aluminum plate (thicknesses 1/4" or greater) in the vertical position. It is expected that welding may have to be accomplished on joints 150 feet long. Manual multi-pass welds can be made in the vertical position; however, this operation would be time consuming since the weldor cannot make long weld passes without frequent starting and stopping. Another factor to consider when making manual welds on large structures is the possibility of weld quality variation due to operator fatigue and judgement. An automatic welding machine should be developed which will have a high degree of functional and repetitive reliability, minimize operator decision and surveillance, and be a relatively low cost flexible unit.

In the Phase I portion of the NASA Contract NAS8-2601, "Determination of TIG Welding Control Parameters and Requirements for the Automation of Out-of-Position Welding," TIG welding equipment was designed, developed, and built for joining aluminum plate material in the vertical position. Motion pictures were taken of a manual welding operation to study and observe the technique employed by the weldor. The weave bead technique used by the weldor was incorporated in the design of two oscillators. The first design (cross seam oscillator) provided a straight transverse oscillating motion. The second design (radius oscillator) changed the direction of the arc as it approached the joint side wall. The arc was directed at the side wall at an angle of 45 degrees. Both oscillators made satisfactory vertical multi-pass automatic welds in three 5456 aluminum plate thicknesses (3/8", 1/2" and 3/4") with amplitudes ranging from 3/16" to 7/16". Good side wall fusion was obtained with both oscillators. The Phase I investigation is reported in Reference (a).

In the Phase II portion of the contract a third oscillator was designed, built and tested. This oscillator provided a cross seam motion, an angular change in the position of the arc, and an adjustment to vary the bead width during the welding operation. The bead width could be varied from 3/8 to 1-1/2" with this oscillator. Acceptable weld passes were made in aluminum plate thicknesses ranging from 3/4 to 2-1/2 inch. The Phase II investigation is reported in Reference (b).

In Phase III a TIG oscillating unit was to be designed, built and delivered to the George C. Marshall Flight Space Center. However, the NASA technical representative requested that this Phase be revised to conduct a MIG feasibility investigation. A supplemental agreement to cover this program redirection was implemented (Reference (c)). Presented in this report is the development work conducted for this feasibility investigation.

1. OBJECTIVE

The objective of the Phase III portion of this program was to investigate the feasibility of applying the oscillating TIG welding techniques and equipment developed in Phase II to the MIG process.

2. MATERIAL

The following aluminum materials were used in the Phase III investigation:

Material	Tnk.	Nominal Chemical Composition Percent Mn	Mg	Cr	Si	Fe	Cu	Zn	Ti
6061S-T6	2-1/2"	.15	1.0	.25	.6	.7	.28	.25	.15
2014	2"	.8	.5	.10	.8	1.0	4.4	.25	.15
43 S Filler (Dia.)	1/16"	.05	.05		5.25	.8	.3	.1	.2

3. EQUIPMENT

3.1 An Airco direct current, 500 amp, constant potential power supply and a Westinghouse Dynamic Reactor were used to weld the test panels. A Honeywell Visicorder was used to record amperage and voltage outputs and torch oscillation. A potentiometer was used to record preheat and inter-pass temperatures (Figure 1).

3.2 The following modifications were made on the Phase II TIG weld oscillator (Figure 2).

3.2.1 The TIG torch holder was removed and replaced with mounts that held the Airco Model AH35A MIG gun in the vertical and horizontal positions. The horizontal mount shown in Figure 3 provided the best position for the gun. In this position the gun was held rigid in the oscillator mount. The lines were attached to a swivel two and one-half feet from the gun which reduced the drag effect of the leads on the oxcillating motion.

3.2.2 The second modification was made to provide dwell of the MIG gun at the joint side walls. The gun dwell time is developed by an oscillating pin which moves in a slotted hole (Figure 3). Dwell time can be varied by changing: The distance through which the pin travels; the oscillation amplitude and speed; and/or the travel speed.

FIGURE 1
AUTOMATIC MIG TEST APPARATUS

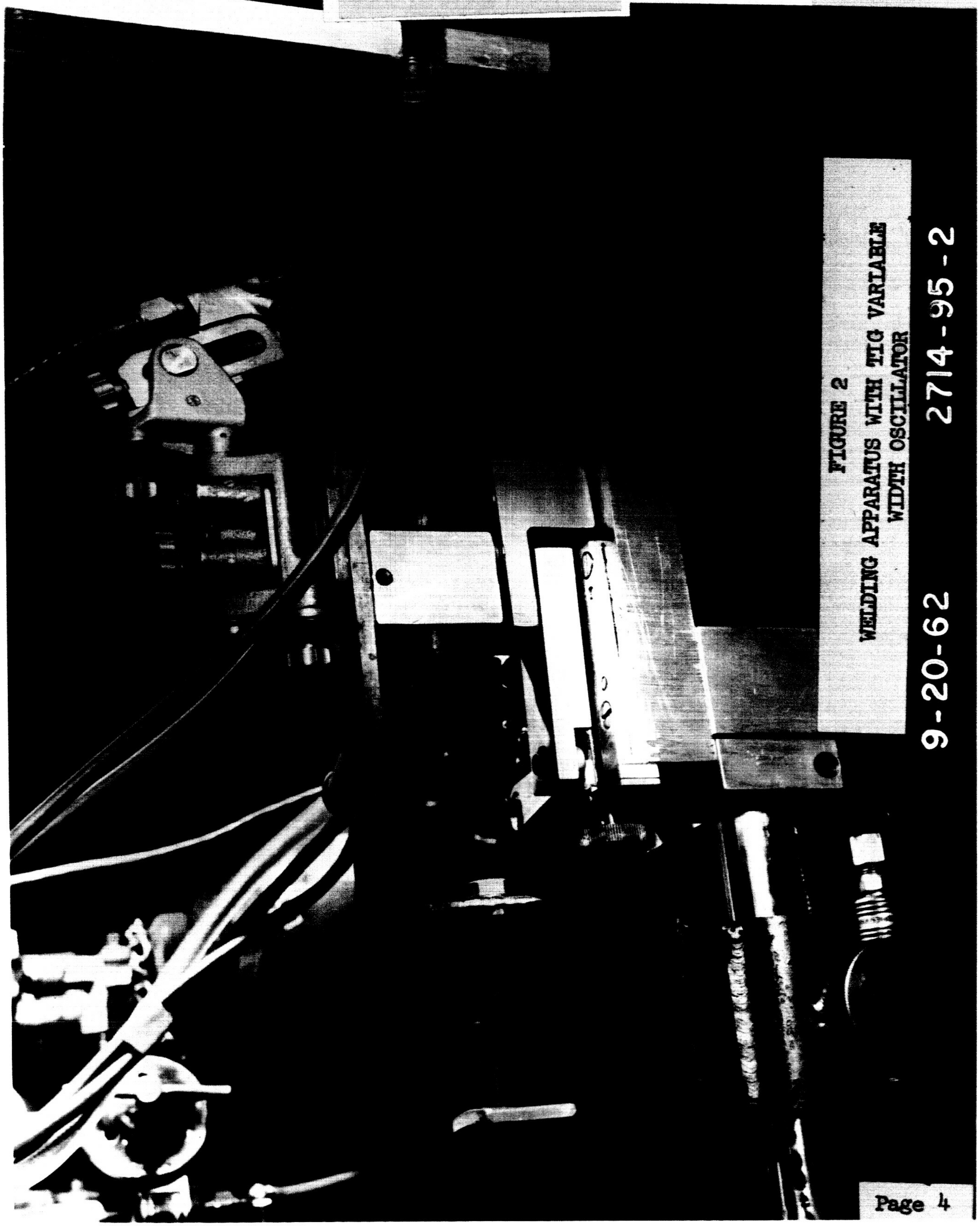


FIGURE 2
WELDING APPARATUS WITH TIG VARIABLE
WIDTH OSCILLATOR

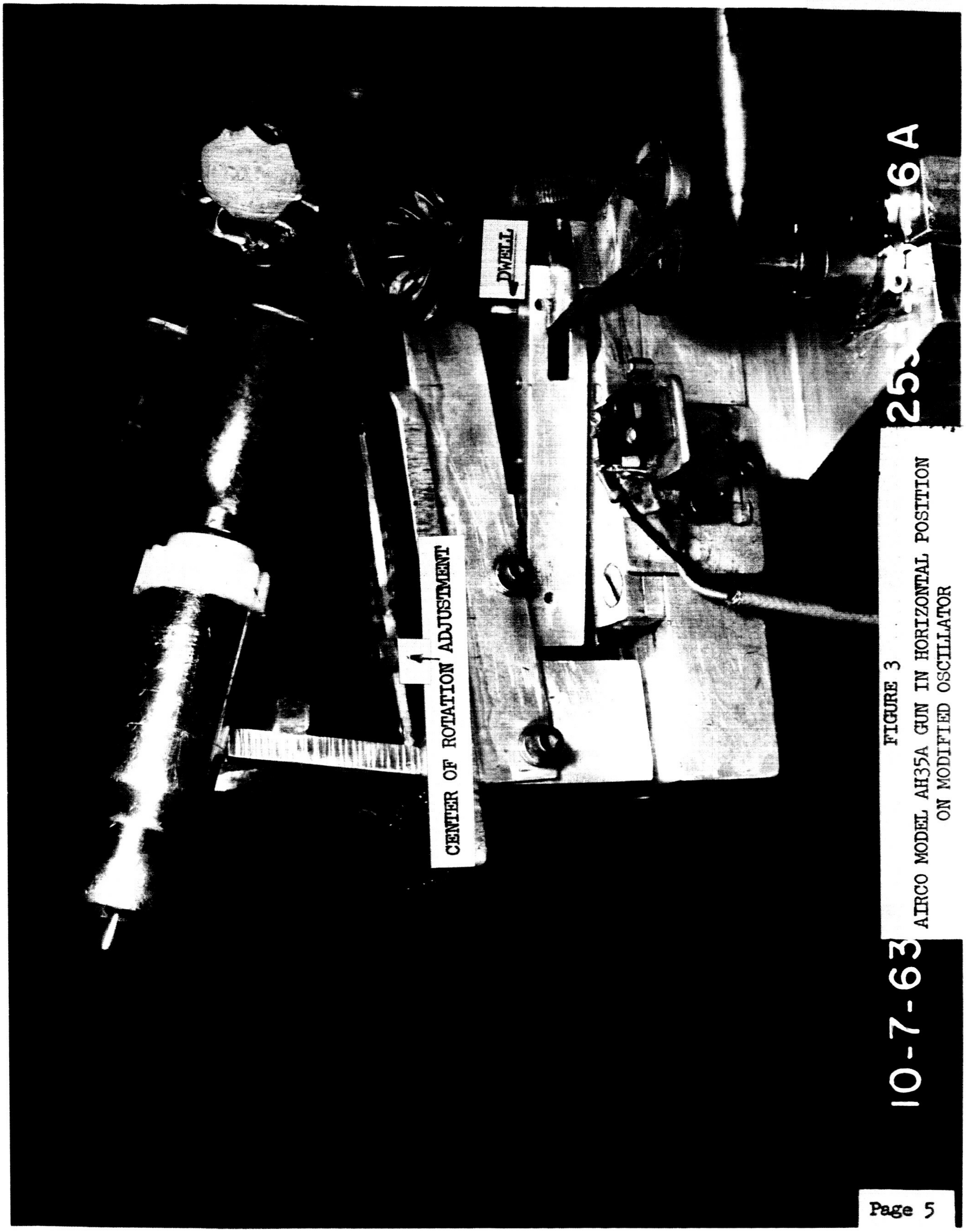


FIGURE 3
AIRCO MODEL AH35A GUN IN HORIZONTAL POSITION
ON MODIFIED OSCILLATOR

3.2.3 A third modification was made which permits adjustment of the gun position with respect to the center of rotation of the oscillator (Figure 3). This modification was required to give greater freedom in selecting oscillation amplitudes and included angles of rotation, since dwell time alone was not sufficient to obtain satisfactory side wall fusion.

4. PROCEDURE

4.1 All of the joints were wire wheel brushed and wiped clean with acetone prior to the welding operation. The welding variables, materials, thicknesses and joint preparations are reported for the test panels in Tables I to IV. The test panels were welded with the equipment shown in Figure 1.

5. RESULTS AND DISCUSSION

5.1 The TIG oscillation unit (Figure 2) was modified to accept the MIG welding gun. The TIG torch mount and wire feed unit were removed and replaced with a clamp which positioned the MIG gun on the unit (Figure 4). The oscillation motion was erratic with the gun in this position. The gun was then mounted in the positions shown in Figures 5 and 6. These improved oscillation motions. The optimum performance was obtained with the gun position shown in Figure 3.

5.2 The TIG oscillation motion was not satisfactory for the MIG gun. Convexed shaped weld beads were made in the groove with the equipment shown in Figure 4. This shape was not desirable since a notch is produced where the weld bead edge intersects the joint side walls. Two modifications were made which eliminated the convex bead shape. The first modification provided dwell at the joint sidewalls as the MIG gun oscillated across the joint. The second modification provided an adjustment to change the center of rotation with reference to the gun. The ability to change the point of rotation, and therefore the angle of arc impingement, greatly improved the ability to obtain side wall fusion. A wider range of oscillation amplitudes were also made available by changing the point of rotation. Typical weld passes made with the modified oscillator are shown in Figures 7 and 8.

5.3 Oscillating the MIG gun in relatively narrow groove widths (1/4 to 1/2 inch) caused arc-out as the consummable electrode approached the side wall when welding was accomplished between 26 to 28 volts. The arc out occurs at the copper guide tube when the gap between it and the joint side wall is less than the gap between the electrode and groove. Reducing the voltage range from 26-28 to 21-23 eliminated the arc out problem in the narrow groove (Table I), however, at the lower voltage range a globular type arc was obtained and the resultant weld had excessive porosity. Increasing the groove joint included angle increases the distance between the guide tube and joint side wall. This change in joint design (See Table II) eliminated arc out. The joint design shown in Table II was welded with a spray type arc (26 to 28) and improved weld quality was obtained. Good side wall and interpass fusion was obtained with the spray type arc (See Figure 9).

5.4 MIG weld passes made in 2-1/2" thick aluminum plate without preheat, were not acceptable.

5.5 The use of a 300 F preheat and inter-pass temperature resulted in satisfactory weld passes.

6. CONCLUSIONS

6.1 Results of this investigation indicate that it is feasible to weld vertical up with the oscillating MIG process.

6.2 MIG welding should be accomplished at a voltage range between 26 to 28.

6.3 Preheat and inter-pass temperatures should be maintained at approximately 300 F when MIG welding is being accomplished on 2 to 2-1/2 inch thick aluminum plate.

7. REFERENCES

(a) Phase I Report NA-62-864, "Determination of TIG Welding Control Parameters and Requirements for the Automation of Out-of-Position Welding" Contract No. NAS8-2601.

(b) Phase II Report NA-62-864-1, "Determination of TIG Welding Control Parameters and Requirements for the Automation of Out-of-Position Welding" Contract No. NAS8-2601.

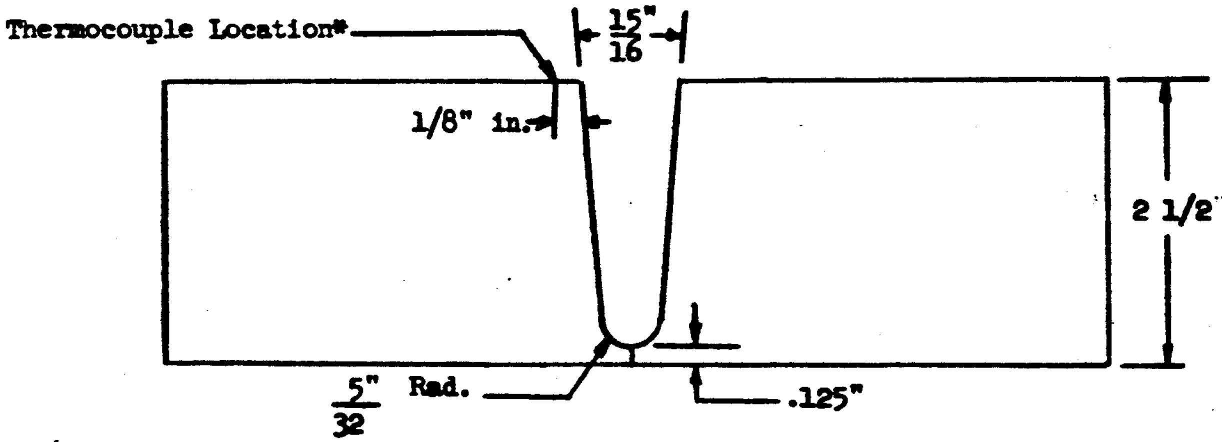
(c) Supplemental Agreement No. 1 to NASA Contract NAS8-2601.

NORTH AMERICAN AVIATION, INC.
INTERNATIONAL AIRPORT
LOS ANGELES 9, CALIFORNIA

TABLE I

DATA SHEET NO. 1
AUTOMATIC MIG WELDING VARIABLES

PANEL NO. 8724
6061 Al MATERIAL
FILLER .063" DIA. 43S
CURRENT DC-SP
TORCH GAS FLOW 150 Cfh HELIUM

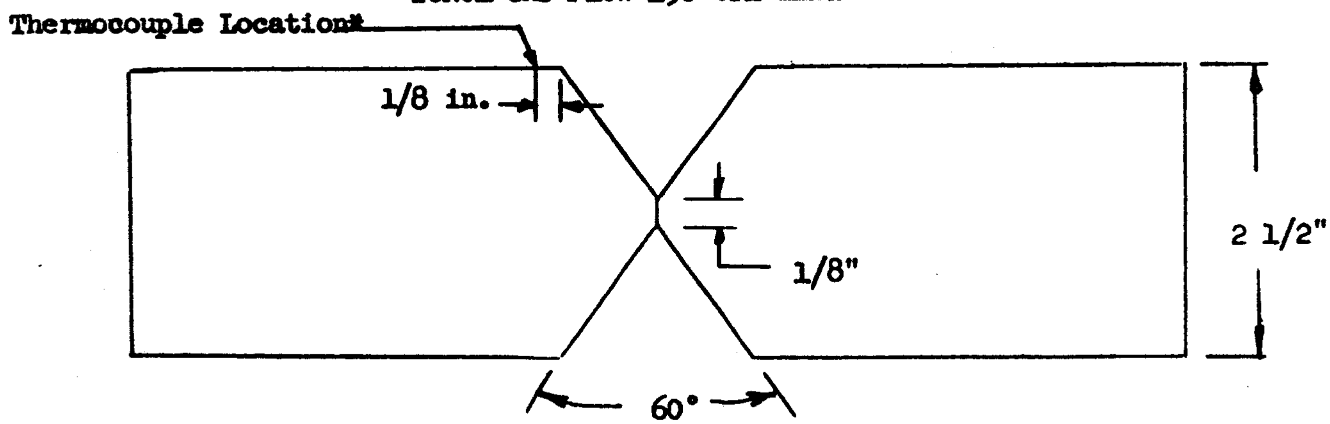


VARIABLES	WELD PASSES										
	1	2	3	4	5	6	7	8	9	10	11
Travel Speed I.P.M.	12	12	6.5	6.5	6.5	6.5	6.5	6.5	4.5	4.5	6.5
Wire Feed I.P.M.	241	245	245	257	257	257	257	257	235	235	235
Amperage	--	210	235	235	235	235	235	235	190	190	190
Voltage	--	21.5	21.5	21.5	21.5	22	23	23	23	23	23
Oscillation Amplitude	No	No	1/4"	11/32"	3/8"	13/16"	--	--	--	--	--
Oscillation Freq. (CPM)	No	No	19	22	44	44	36	36	41	41	41
Preheat	320F	320F	320F	320F	320F	320F	320F	320F	320F	320F	320F

* Thermocouple was located at the weld stop end of the 18 inch long test panel.

TABLE II
DATA SHEET NO. 2
AUTOMATIC MIG WELDING VARIABLES

PANEL NO. 8725
6061 Al MATERIAL
FILLER .063" DIA. 43S
CURRENT DC-SP
TORCH GAS FLOW 150 Cfh HELIUM



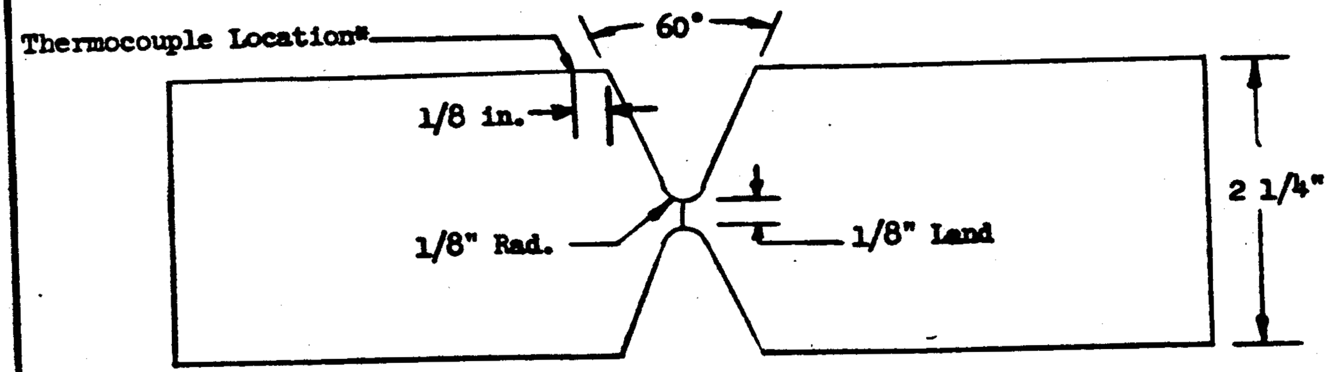
VARIABLES	SIDE "A" WELD PASSES									
	1	2	3	4	5	6	7	8	9	10
Travel Speed I.P.M.	Manual TIG Weld	12	12	9.5	9.5	6.5	6.5	6.5	6.5	4.5
Wire Feed I.P.M.		241	241	208	208	212	194	194	194	194
Amperage		220	210	200	200	200	170	180	180	200
Voltage		26	27	26	27	27	27	27	27	28
Oscillation Amplitude		5/16"	7/16"	9/16"	11/16"	3/4"	29/32"	7/8"	1"	1-1/8"
Oscillation Freq. (CPM)		53	53	51	41	40	40	41	40	37
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F

VARIABLES	SIDE "B" WELD PASSES										
	1	2	3	4	5	6	7	8	9	10	11
Travel Speed I.P.M.	12	12	9.5	9.5	9.5	9.5	6.5	4.5	4.5	6.5	4.5
Wire Feed I.P.M.	248	248	202	208	208	208	212	194	175	175	194
Amperage	230	230	180	190	210	210	200	190	170	165	180
Voltage	27	27	28	27	28	28	27	27	28	27	27
Oscillation Amplitude	5/16"	7/16"	9/16"	5/8"	5/8"	11/16"	7/8"	1-1/16"	1-1/8"	1-11/32"	1-5/16
Oscillation Freq. (CPM)	51	47	41	41	51	51	36	36	41	51	51
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F

* Thermocouple was located at the weld stop end of the 18 inch long test panel.

TABLE III
DATA SHEET NO. 3
AUTOMATIC MIG WELDING VARIABLES

PANEL NO. 5214
6061 ALUMINUM
FILLER .063" DIA. 43S
CURRENT DC-SP
TORCH GAS FLOW 150 Cfh HELIUM



VARIABLES	SIDE "A" WELD PASSES										
	1	2	3	4	5	6	7	8	9	10	11
Travel Speed I.P.M.	32.5	17.5	12	9.5	9.5	9.5	9.5	6.5	6.5	9.5	4.5
Wire Feed I.P.M.	212	235	212	198	202	202	208	212	212	183	183
Amperage	165	195	235	160	150	140	200	160	210	180	190
Voltage	24	24	28	22	28	26	26	27	27	27	27
Oscillation Amplitude	No	1/4"	7/16"	1/2"	9/16"	11/16"	13/16"	7/8"	1"	1"	1 1/8"
Oscillation Freq. (CPM)	No	78	--	48	48	42	48	32	32	--	36
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F

VARIABLES	SIDE "B" WELD PASSES									
	1	2	3	4	5	6	7	8	9	10
Travel Speed I.P.M.	17.5	17.5	12.0	9.5	6.5	6.5	4.5	4.5	6.5	4.5
Wire Feed I.P.M.	245	245	220	202	202	202	202	202	175	194
Amperage	180	250	225	200	200	220	220	200	180	200
Voltage	27	27	26	26	27	26	27	26	27	27
Oscillation Amplitude	No	No	1/4"	5/16"	5/8"	3/4"	7/8"	1 1/16"	1 3/16"	1 3/8"
Oscillation Frequencies (CPM)	No	No	--	44	44	44	44	55	40	40
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F

* Thermocouple was located at the weld stop end of the 18 inch long test panel.

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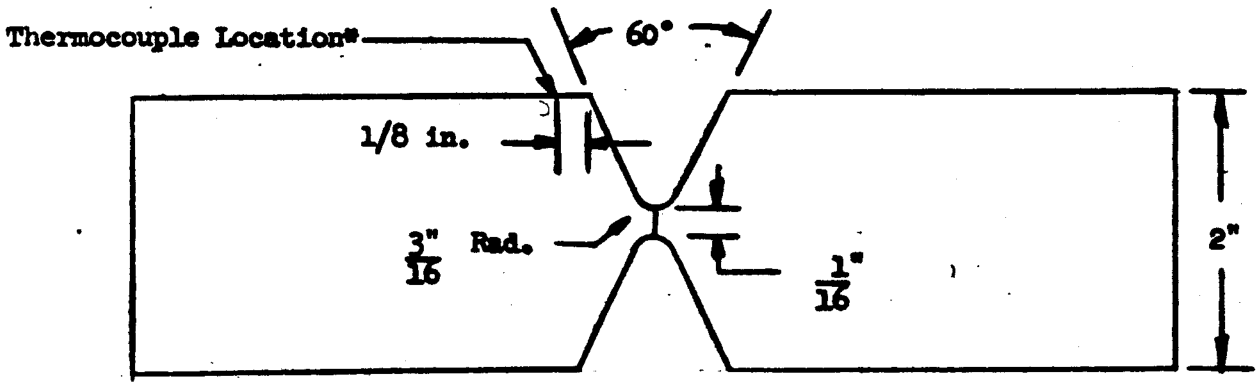
TABLE IV
DATA SHEET NO. 4
AUTOMATIC MIG WELDING VARIABLES

PANEL NO. 52146
2014 ALUMINUM
FILLER .063" DIA. 43S
CURRENT DC-SP
TORCH GAS FLOW 150 Cfh HELIUM



VARIABLES	SIDE "A" WELD PASSES 1	2	3	4	5	6	7	8	9	10	11
Travel Speed I.P.M.	32.5	17.5	17.5	12.5	9.5	6.5	6.5	6.5	6.5	4.5	4.5
Wire Feed I.P.M.	241	175	175	241	202	202	198	217	217	188	217
Amperage	165	160	160	235	200	200	180	185	195	180	200
Voltage	24	25	24	26	28	27	29	29	28	28	28
Oscillation Amplitude	1/8"	5/16"	3/8"	1/2"	5/8"	7/8"	1"	1 1/8"	1"	1 5/16"	1 1/2"
Oscillation Frequencies (CPM)	54	54	54	54	42	42	36	36	54	54	30
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F	300F

VARIABLES	SIDE "B" WELD PASSES 1	2	3	4	5	6	7	8	9
Travel Speed I.P.M.	32.5	12.5	12.5	12.5	6.5	6.5	6.0	4.5	4.5
Wire Feed I.P.M.	241	235	217	217	212	202	217	217	194
Amperage	210	210	225	210	220	200	210	200	190
Voltage	23	26	28	27	28	26	28	28	27
Oscillation Amplitude	No	3/16"	1/4"	3/8"	1/2"	5/8"	7/8"	1"	1 1/4"
Oscillation Frequencies (CPM)	No	--	--	--	48	42	36	41	41
Preheat	300F	300F	300F	300F	300F	300F	300F	300F	300F

* Thermocouple was located at the weld stop end of the 18 inch long test panel.

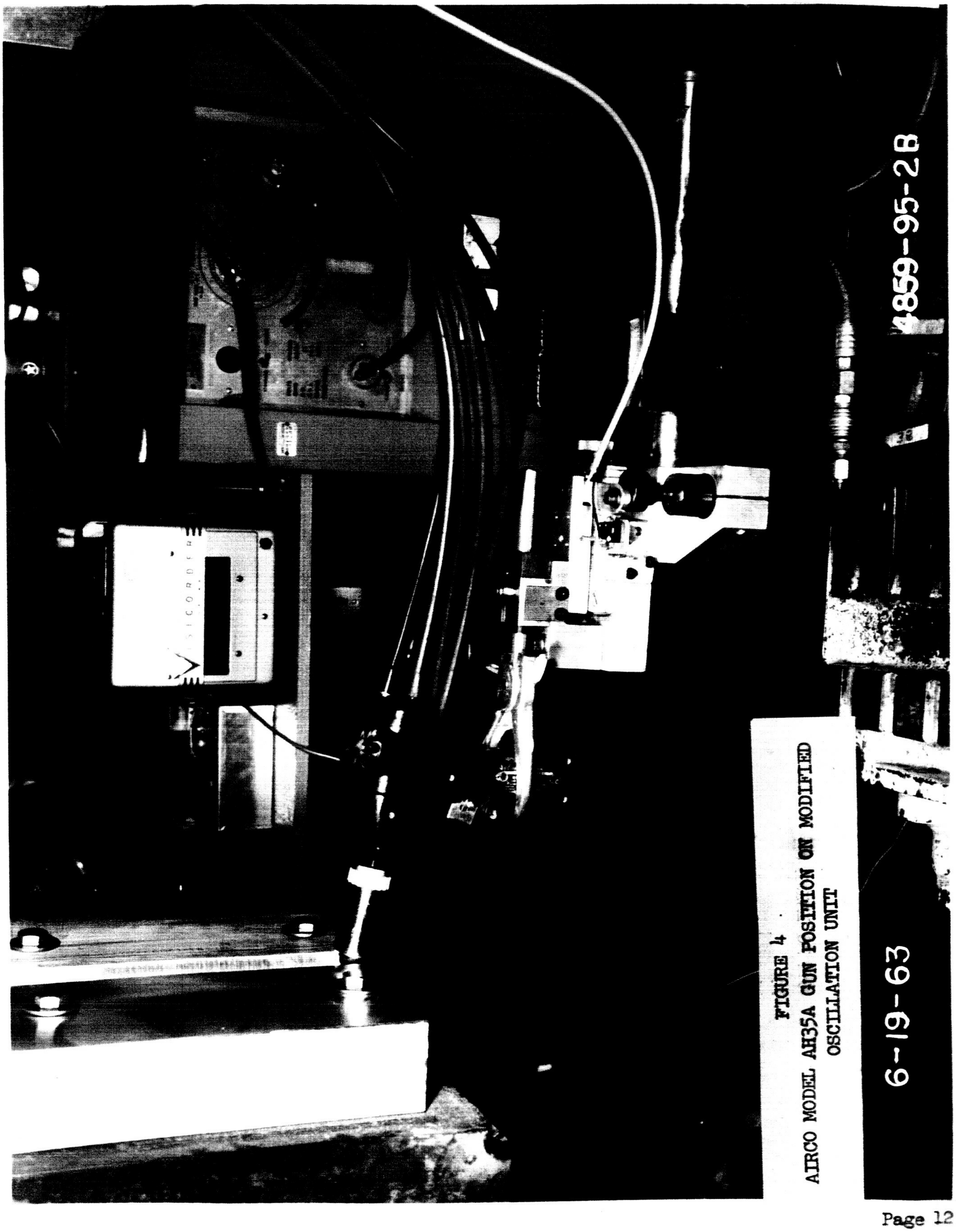


FIGURE 4
AIRCO MODEL AH35A GUN POSITION ON MODIFIED
OSCILLATION UNIT

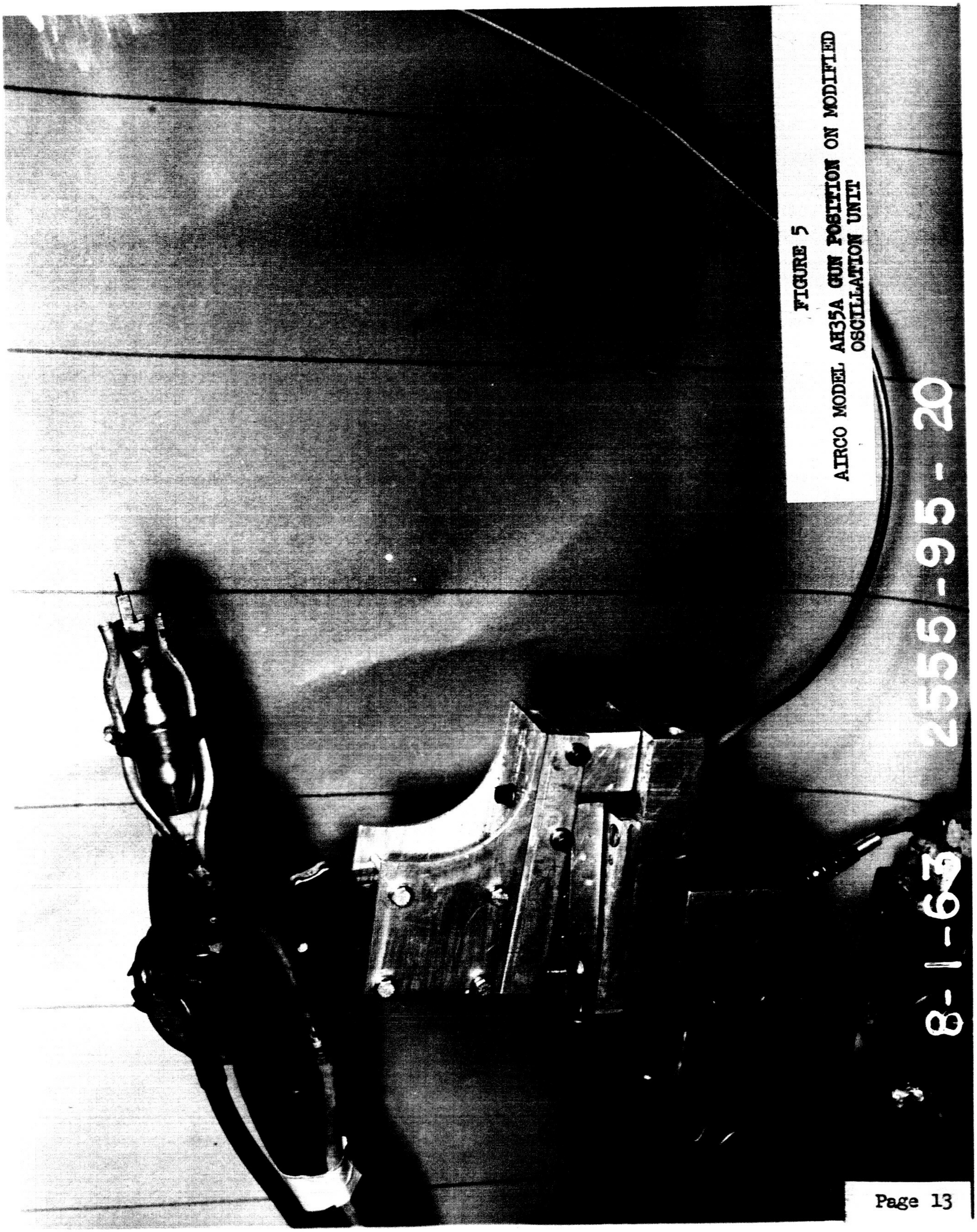


FIGURE 5

AIRCO MODEL AH35A GUN POSITION ON MODIFIED OSCILLATION UNIT

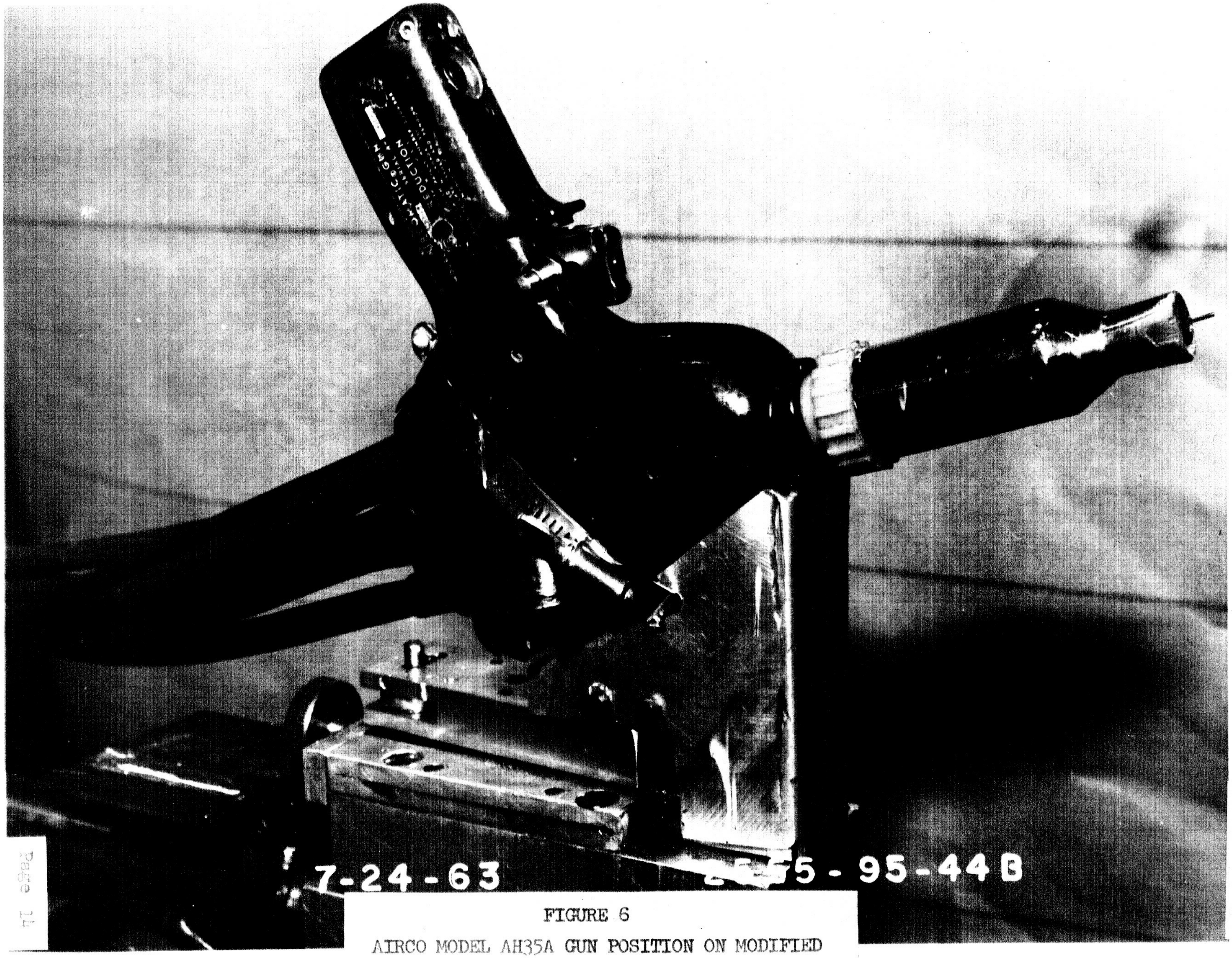


FIGURE 6

AIRCO MODEL AH35A GUN POSITION ON MODIFIED OSCILLATION UNIT

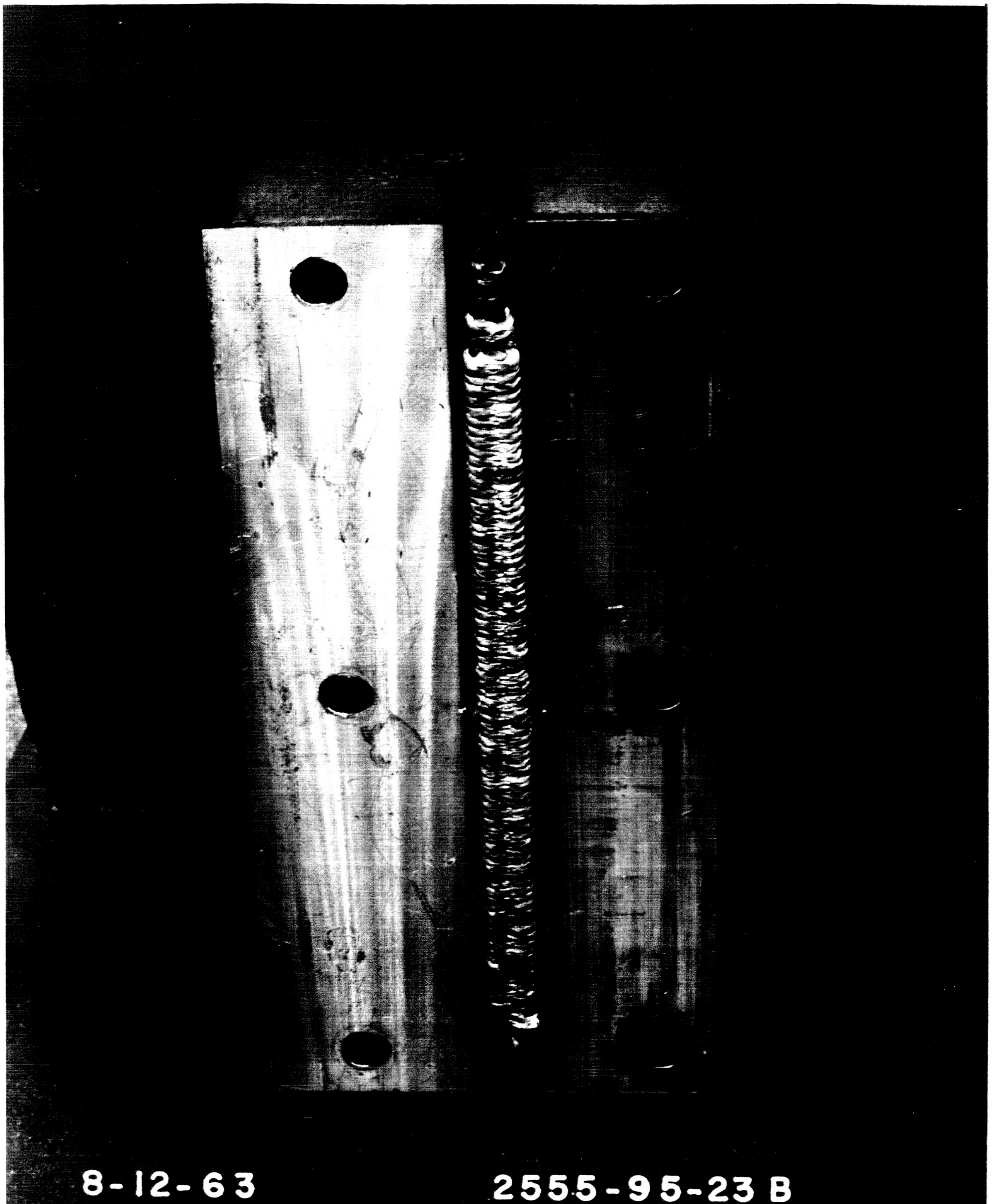


FIGURE 7

OSCILLATING MIG WELD PASS MADE IN THE GROOVE

FIGURE 8
OSCILLATING MIG WELD COVER PASS

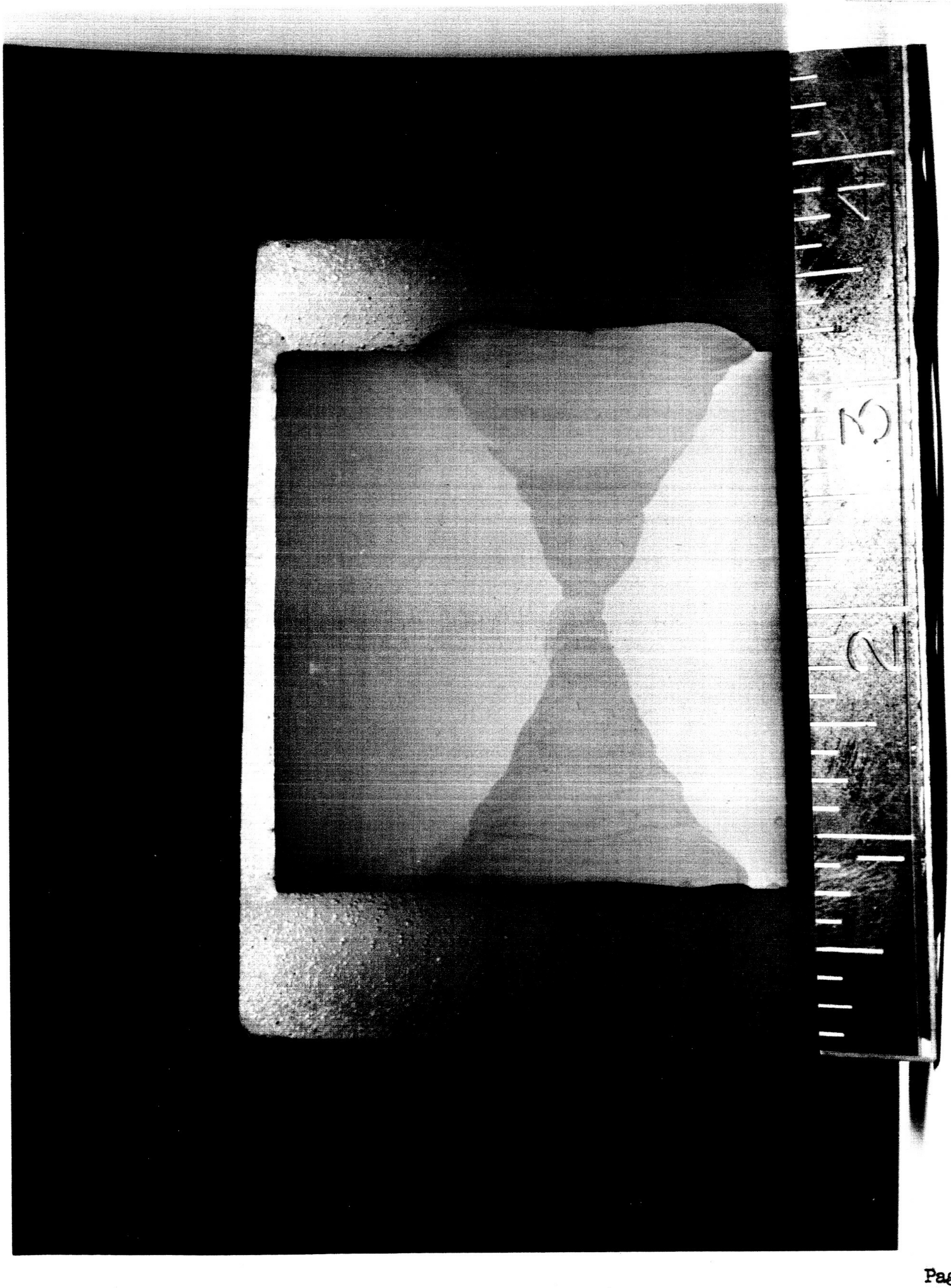


FIGURE 9
PHOTOMACROGRAPH OF OSCILLATING MIG WELD JOINT